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(54) **IN-LINE OPTOELECTRONIC DEVICE PACKAGING**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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**Related U.S. Application Data**

(63) Continuation of application No. 09/425,253, filed on Oct. 22, 1999, now Pat. No. 6,390,689.

(60) Provisional application No. 60/105,171, filed on Oct. 22, 1998.

(51) **Int. Cl.**<sup>7</sup> ..... **G02B 6/36**

(52) **U.S. Cl.** ..... **385/88; 385/73; 385/75**

(58) **Field of Search** ..... 385/53–55, 58, 385/60, 66, 70, 72, 73, 75, 77, 78, 84, 88–92

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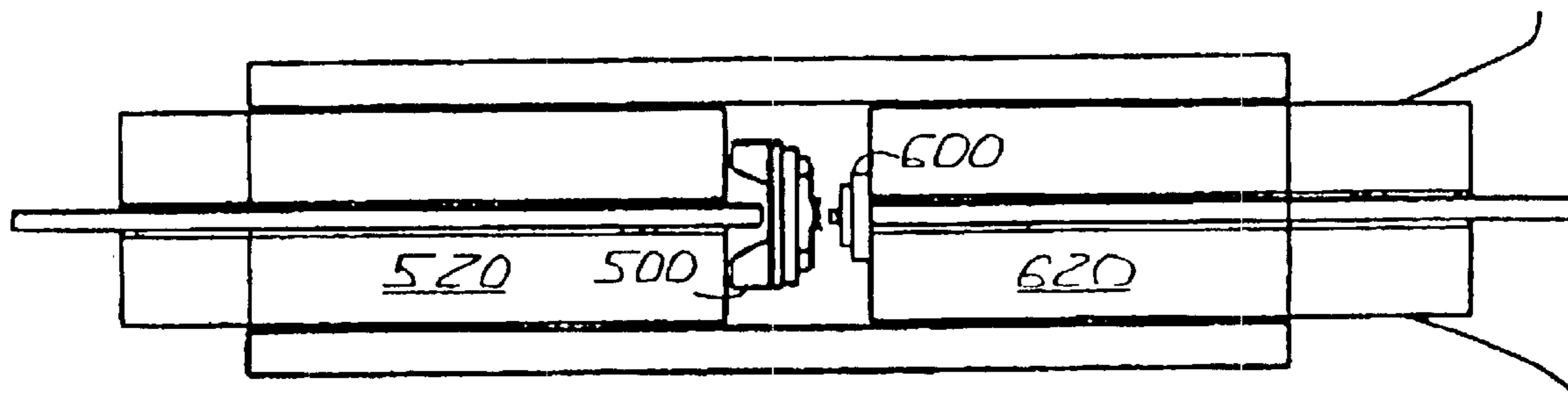
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(57) **ABSTRACT**

A fiber connector that facilitates alignment of and electrical communication with electrooptical devices on an optical fiber or interposed between optical fibers. An embodiment of in-line optoelectronic device packaging constructed according to principles of the invention includes a ferrule configured to receive an optical fiber with an optoelectronic device mounted on one end of the ferrule, for alignment with the fiber. Electrically-conductive deposits along the side of the ferrule supply electrical energy to or conduct electrical signals from the optoelectronic device. The optoelectronic device-carrying ferrule is inserted in a ceramic sleeve. Another ferrule, maintaining another optical fiber, also is inserted in the ceramic sleeve. Another embodiment constructed according to principles of the invention includes a second optoelectronic device mounted on the second ferrule. The electrically-conductive deposits permit ready serial deployment of optoelectronic devices between the optical fibers maintained by the ferrules in the sleeve.

**11 Claims, 3 Drawing Sheets**



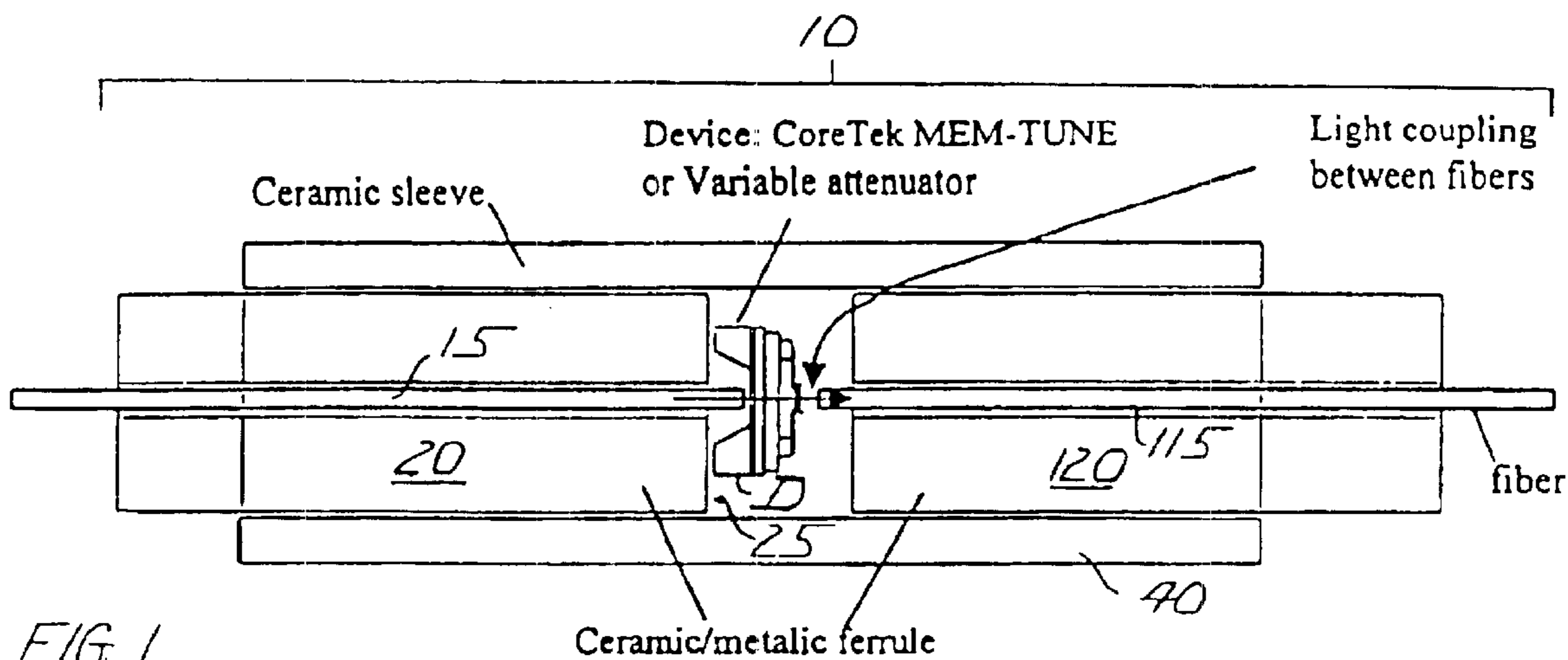


FIG. 1

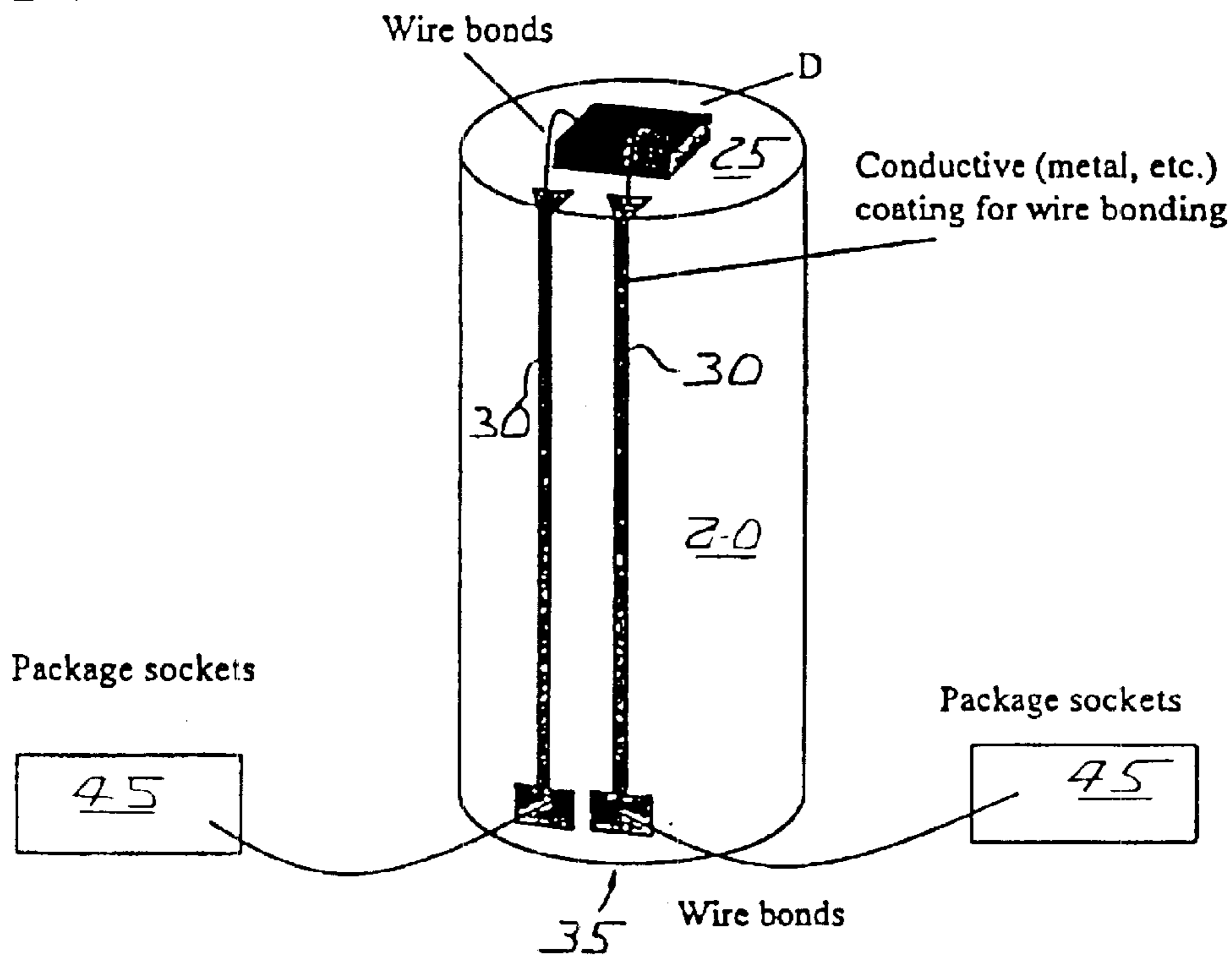


FIG. 2

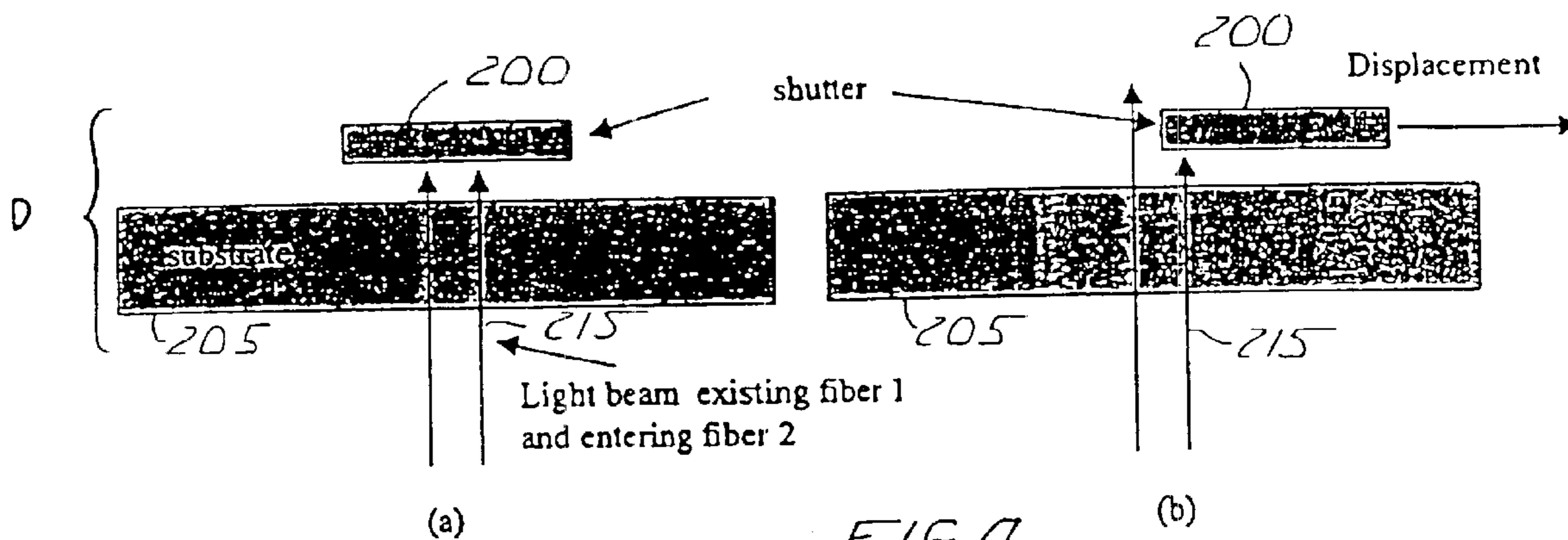


FIG. 3

FIG. 4

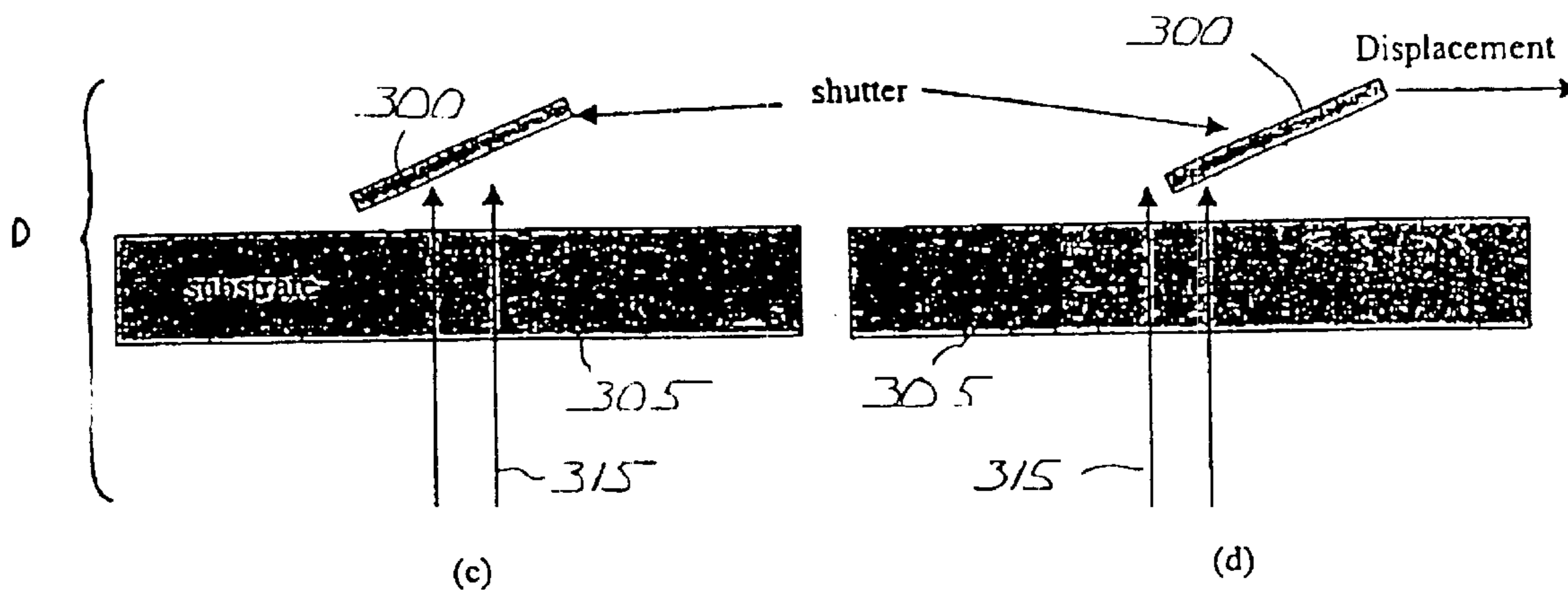


FIG. 5

FIG. 6

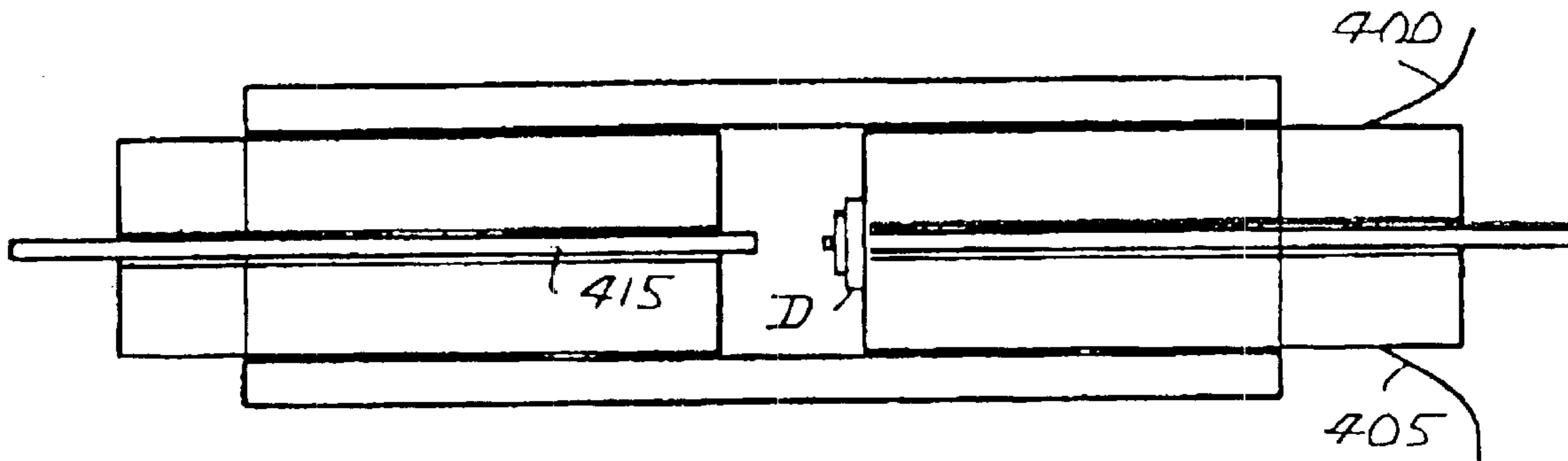


FIG. 7

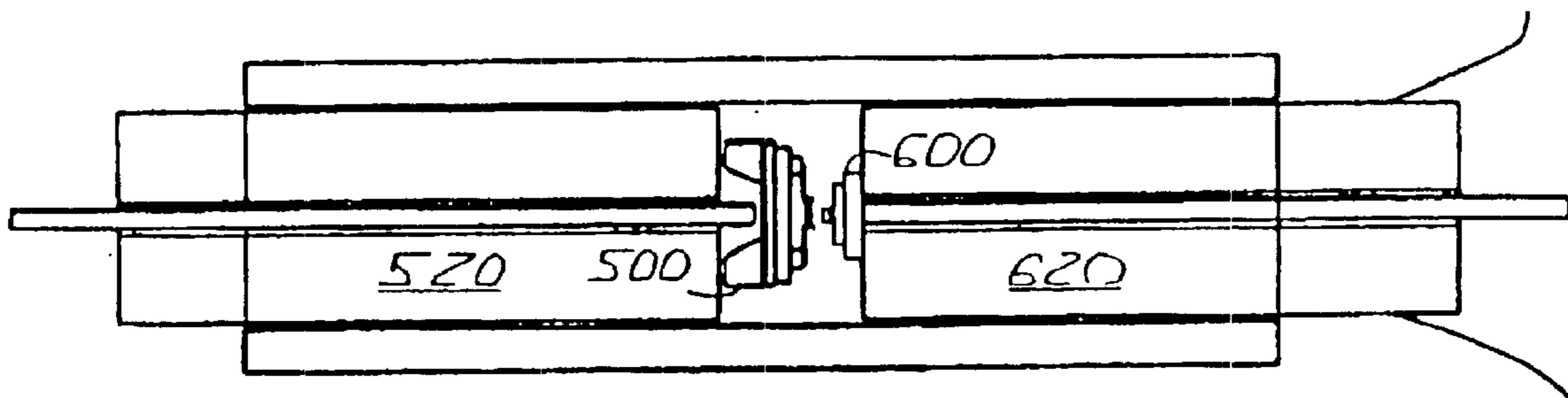


FIG. 8

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## IN-LINE OPTOELECTRONIC DEVICE PACKAGING

### REFERENCE TO PENDING PRIOR PATENT APPLICATION

This is a continuation of prior application Ser. No. 09/425, 253 filed Oct. 22, 1999, now U.S. Pat. No. 6,390,689, by Masud Azimi et al. for IN-LINE OPTOELECTRONIC DEVICE PACKAGING.

### REFERENCE TO EARLIER PATENT APPLICATION

This Application claims the benefit of U.S. Provisional Application No. 60/105,171, filed Oct. 22, 1998, by M. Azimi et al., entitled *Novel Packaging Technology For In-line Optoelectronic Devices*, which application is hereby incorporated herein by reference.

### FIELD OF THE INVENTION

The invention relates to optoelectronic device-optical fiber installation and alignment.

### BACKGROUND OF THE INVENTION

Fiber optics is a branch of physics based on the transmission of light through transparent fibers. Individual or bundled optical fibers can carry light for hundreds of miles. An optical fiber has a highly transparent core, typically constructed from glass or plastic and encased in a cladding. Light from a laser, incandescent light bulb or other source enters one end of the optical fiber. Light traveling through the core is contained by the cladding because the inside surface of the cladding bends or reflects light inwardly. At the other end of the fiber, a detector, such as a photosensitive device or the human eye, receives the light.

Commercially available high-tolerance fiber ferrules closely received in corresponding sleeves, commonly referred to as fiber connectors, often are used to couple serial individual fibers. These ferrules, normally made of Zirconia, Alumina or metals, each are made with a through-hole for receiving a fiber. The ferrules are precisely manufactured to provide less than 1 micron center-to-center tolerance between serially-aligned ferrules. When retained in a sleeve, the ferrules maintain the cores of the fibers with high-precision alignment, which results in less than 0.5 dB coupling loss.

Many optical applications rely on interposing optoelectronic devices between aligned fibers. These optoelectronic devices often require electrical energy in order to operate. Where the fibers are coupled with fiber connectors, placement of the optoelectronic device for optimal transmission therethrough is problematic. Delivering electrical energy to or monitoring electrical signals from the optoelectronic device also is difficult.

What is needed is a fiber connector that facilitates alignment of and electrical communication with optoelectronic devices on or between optical fibers.

### SUMMARY OF THE INVENTION

The invention provides for alignment of and electrical communication with optoelectronic devices on or between optical fibers. In addition to inter-fiber submicron alignment accuracy, the invention provides low-cost packaging and electrical connectivity for optoelectronic devices and detectors.

Packaging in-line devices, such as CoreTek's tunable filter and variable optical attenuator, is disclosed. The packaging takes advantage of commercially available high tol-

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erance fiber ferrules and corresponding sleeves normally used for fiber connectors. These ferrules, normally made of Zirconia, Alumina or metals, each are made with a through-hole for receiving a fiber. The ferrules are precisely manufactured to within less than 1 micron center-to-center tolerance between ferrules. When placed inside a sleeve, the ferrules maintain the cores of the fibers with high-precision alignment, which results in less than 0.5 dB coupling loss.

An embodiment constructed according to principles of the invention includes a ferrule configured to receive an optical fiber. An optoelectronic device is mounted on one end of the ferrule, for alignment with the fiber. Electrically-conductive deposits along the side of the ferrule supply electrical energy to or conduct electrical signals from the optoelectronic device. The optoelectronic device-carrying ferrule is inserted in a ceramic sleeve. Another ferrule, maintaining another optical fiber, also is inserted in the ceramic sleeve. The two ferrules are aligned in the sleeve and capable of transmitting light with minimal coupling loss.

Another embodiment constructed according to principles of the invention includes a second optoelectronic device mounted on the second ferrule. Electrically-conductive deposits on the second ferrule provide for electrical communication with and permit ready interposition of optoelectronic devices, such as a variable attenuator or VCSEL laser emitter, between the optical fibers maintained by the ferrules in the sleeve.

These and other features of the invention will be appreciated more readily in view of the drawings and detailed description below.

### BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in detail below with reference to the following figures, throughout which similar reference characters denote corresponding features consistently, wherein:

FIG. 1 is an axial cross-sectional detail view of an embodiment of in-line optoelectronic device packaging constructed according to principles of the invention;

FIG. 2 is a top side elevational view of an embodiment of an optoelectronic device mounted on a ferrule constructed according to principles of the invention;

FIGS. 3 and 4 are schematic representations of an embodiment of an attenuating optical modulator, articulated to and from a displaced position, respectively, constructed according to principles of the invention;

FIGS. 5 and 6 are schematic representations of another embodiment of an attenuating optical modulator, articulated to and from a displaced position, respectively, constructed according to principles of the invention;

FIG. 7 is an axial cross-sectional detail view of another embodiment of in-line optoelectronic device packaging constructed according to principles of the invention; and

FIG. 8 is an axial cross-sectional detail view of a further embodiment of in-line optoelectronic device packaging constructed according to principles of the invention.

### DETAILED DESCRIPTION OF THE INVENTION

The invention is a fiber connector that facilitates alignment of and electrical communication with electrooptical devices on an optical fiber or interposed between optical fibers.

Referring to FIG. 1, an embodiment of the present packaging 10 is shown incorporating a device D, such as a CoreTek tunable filter. The filter requires axial, inter-fiber positional accuracy within 0.5 micron.

The packaging 10 is constructed as follows: First, a fiber 15 is positioned inside a ferrule 20. The ferrule 20 is

constructed and machined in a manner well known in the art, thus is not described here.

An optoelectronic device D, such as the filter, is positioned on a first end **25** of the ferrule **20** and aligned to optimize throughput or other optical performance criteria. Once the device D and fiber **15** are aligned, the device D is fixed to the ferrule **20** with an adhesive or thin film solder (not shown) pre-deposited on the joining surfaces.

Referring also to FIG. 2, once the device D is bonded to the ferrule **20**, the device D is electrically connected to electrical conductors, shown as metal pads **30**, deposited on the ferrule **20**. The use of deposited electrically conductive films as electrical connections are advantageous to the invention. The metal pads (strips) **30** run from the first end **25** of the ferrule **20**, along the side of the ferrule **20**, to a second end **35** of the ferrule **20**. Although two metal pads **30** are shown, any number of metal pads **30** may be deposited on the ferrule **20** as needed.

Once the device D is connected to the electrical conductors **30**, the ferrule **20** is inserted into a metal or ceramic sleeve **40**. The ferrule **20** and sleeve **40** are configured and toleranced to provide optimal coaxial alignment among the fiber **15**, ferrule **20** and sleeve **40**.

Once inserted in the ceramic sleeve **40**, at the second end **35** of the ferrule **20**, the metal strips **30** are electrically connected to feed-throughs or sockets **45**. This may be achieved with wire bonding or any suitable connection convention.

Having assembled the first ferrule **20** with the sleeve **40**, a second ferrule **120**, carrying a second fiber **115**, is inserted into the sleeve **40**. As mentioned above, the first ferrule **20** and second ferrule **120** are precisely manufactured so that, when inserted into the sleeve **40**, the first fiber **15** and second fiber **115** are in good alignment and occasion minimal light transmission loss.

In one embodiment, the device D is a micromachined tunable Fabry-Perot filter, such as a CoreTek MEM-TUNE filter.

Referring to FIGS. 3 and 4, in another embodiment, the device D is a micromachined microelectromechanical (MEM) optical modulator which may function as a variable attenuator. This embodiment of a MEM device includes a movable reflective or absorptive "shutter" **200**. The shutter **200** translates relative to a light-passing substrate **205** normal to the direction **215** of the optical beam.

Referring to FIGS. 5 and 6, in a further embodiment, the device D also is a micromachined MEM optical modulator variable attenuator. This embodiment, however, includes a tiltable "shutter" **300** which rotates angularly with respect to the direction **315** of the optical beam.

Referring to FIG. 7, an additional embodiment of the ferrule-mounted device D is a detector. The detector, responsive to light transmitted from the first fiber **415** therethrough, generates a corresponding electrical signal that may be perceived by a sensor (not shown) via electrical leads **400** and **405**.

Referring to FIG. 8, yet another embodiment of an optoelectronic device constructed according to principles of the invention includes mounting an optical device on the first ferrule **520** as well as mounting an optical device on the second ferrule **620**. As with the first embodiment, a tunable filter **500** is mounted on the first ferrule **520**. Additionally, as with the foregoing embodiment, a detector **600** is mounted on the second ferrule **620**. This combination forms a spectrometer.

The invention is not limited to the foregoing, but encompasses all improvements and substitutions consistent with the principles of the invention.

What is claimed is:

1. An optoelectronic assembly adapted to be interposed between optical fibers comprising:

a ferrule having a first end and a second end;

an optoelectronic device mounted on said first end of said ferrule;

a plurality of electrical conductors mounted on said ferrule from a first portion to a second portion, said first portion configured at said first end of the ferrule and said second portion configured a first given distance from said first end of said ferrule toward said second end of said ferrule, each said electrical conductor being electrically insulated from adjacent ones of said electrical conductors, said electrical conductors enabling communication of electrical signals from said optoelectronic device;

a sleeve configured to receive said first end of said ferrule therein to a second given distance, wherein said second given distance is less than said first given distance so as to position said second portion outside of said sleeve; and

an energy supply selectably electrically connectable to ones of said electrical conductors at said second portion outside of said sleeve.

2. The ferrule of claim 1, wherein each said electrical conductor is an electrically-conductive film.

3. The ferrule of claim 1, wherein each said electrical conductor is constructed from metal.

4. The ferrule of claim 1, including a plurality of electrical connectors, each connected to selected ones of said electrical conductors, enabling electrical communication with the optoelectronic device, a feed-through, a socket and combinations thereof.

5. The assembly of claim 1, said optoelectronic device being selected from a detector, a filter, a laser source, a sensor, a VCSEL, a CCD, an optical modulator, a variable attenuator and combinations thereof.

6. The assembly of claim 1, further comprising:

a second ferrule;

said sleeve being configured to receive said second ferrule.

7. The assembly of claim 6, said optoelectronic device being interposed between said ferrule and said second ferrule.

8. The assembly of claim 6, further comprising a second optoelectronic device mounted on said second ferrule;

said second ferrule including a second plurality of electrical conductors enabling electrical communication with said second optoelectronic device.

9. The assembly of claim 8, said second optoelectronic device being interposed between said ferrule and said second ferrule.

10. The assembly of claim 8, said second optoelectronic device being selected from a detector, a filter, a laser source, a sensor, a VCSEL, a CCD, an optical modulator, a variable attenuator and combinations thereof.

11. The assembly of claim 8, further comprising a second energy supply selectably electrically connectable to ones of said second plurality of electrical conductors.